



# All-Silicon Active Antennas for High Performance and low-cost mmWave Systems

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# Agenda

- High Performance/Low Cost mmWave System notional requirements
  - CPE High level requirements
- Anokiwave IC details (Gen 1, 2, 3)
- General architecture options that we will draw upon for CPE (quad, split, 8-channel, 2-pol)
- Look at some specific CPE examples (details with numbers)
  - CPE summary table
- AW IC features and functions that support all CPEs
  - ZERO-CAL™, 3DBS, FBS, etc.
- When you buy AW: DK and GUI details
- AW should be your preferred IC provider

# CPE Notional Requirements

# CPE Requirements

- Power
  - Should be powered over Ethernet (PoE+ = 25W max)
    - Assume 50% allocated to analog functions (~12 W max)
      - Include BFIC, control FPGA, IFIC synthesizer, power supply  $\eta$
- Linear EIRP
  - Should be close to 40 dBm per polarization as possible
- Rx NF Sensitivity
  - Should be as low as possible
- Scan Volume
  - Azimuth of +/-60 degrees
  - Elevation +/-20 degrees or less
- Cost
  - Should be lower cost -> simple, minimum IC parts
- Size
  - Dependent on array size

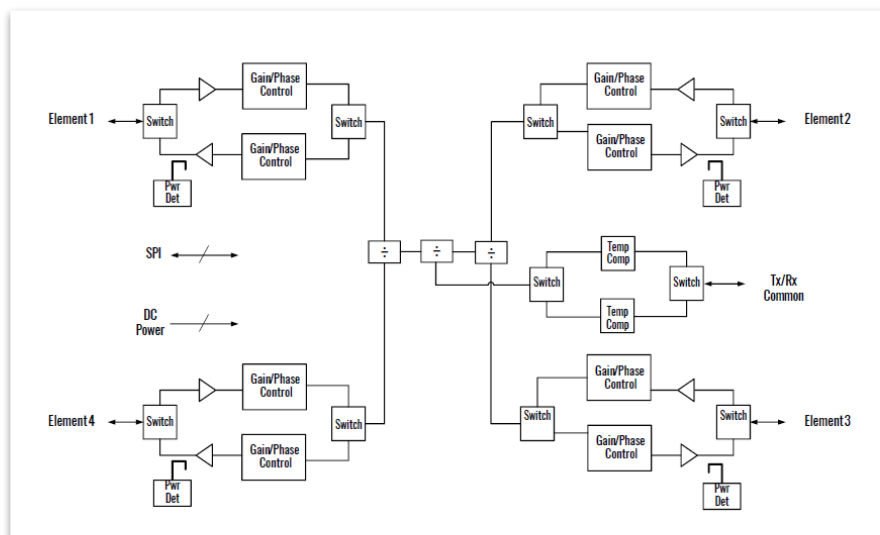
# Anokiwave IC Portfolio

# Anokiwave Active Antenna IC Portfolio

| Market                            | Band      | Product Family  | Part Number | Tx Pwr   | Rx NF  | Package               | Description                          |
|-----------------------------------|-----------|-----------------|-------------|----------|--------|-----------------------|--------------------------------------|
| 5G Communications Active Antennas | 26 GHz    | Silicon Core IC | AWMF-0135   | 10 dBm   | 5 dB   | QFN                   | 5G Tx/Rx Quad Core IC                |
|                                   |           | Silicon Core IC | AWMF-0139   | 14 dBm   | 5.5 dB | WLCSP                 | 5G Tx/Rx Quad Core IC                |
|                                   | 28 GHz    | Silicon Core IC | AWMF-0108   | 9 dBm    | 5 dB   | QFN                   | 5G Tx/Rx Quad Core IC                |
|                                   |           |                 | AWMF-0158   | 15.5 dBm | 4.8 dB | WLCSP                 | 5G Tx/Rx Quad Core IC                |
|                                   | 39 GHz    | Silicon Core IC | AWMF-0144   | 15 dBm   | -      | WLCSP                 | 5G Tx Quad Core IC                   |
|                                   |           |                 | AWMF-0145   | -        | 4.5 dB | WLCSP                 | 5G Rx Quad Core IC                   |
|                                   |           |                 | AWMF-0156   | 13.5 dBm | 6.5 dB | WLCSP                 | 5G Tx/Rx Quad Core IC                |
| Active Antenna Innovator Kits     | 24/26 GHz | Active Antenna  | AWA-0142    | -        | -      | Planar Active Antenna | 256 Element Innovator Kit            |
|                                   | 28 GHz    | Active Antenna  | AWMF-0129   | -        | -      | Planar Active Antenna | 64 Element Innovator Kit             |
|                                   |           |                 | AWA-0134    | -        | -      | Planar Active Antenna | 256 Element Innovator Kit            |
| SATCOM Active Antennas            | K-Band    | Silicon Core IC | AWS-0102    | -        | 3.4 dB | QFN                   | 4 or 8-element Rx Quad Core IC       |
|                                   | Ka-Band   | Silicon Core IC | AWMF-0109   | 12 dBm   | -      | QFN                   | 4 or 8-element Tx Quad Core IC       |
| Multi-Market                      | Ku-Band   | Silicon Core IC | AWMF-0117   | 12 dBm   | 3 dB   | WLCSP                 | Intelligent Gain Block IC w/ switch  |
|                                   |           |                 | AWMF-0141   | 13.5 dBm | 1.7 dB | WLCSP                 | Intelligent Gain Block IC w/o switch |
|                                   | Ka-Band   | Silicon Core IC | AWMF-0116   | 12 dBm   | 5 dB   | WLCSP                 | Intelligent Gain Block IC w/ switch  |
|                                   |           |                 | AWMF-0143   | 13 dBm   | 2 dB   | WLCSP                 | Intelligent Gain Block IC w/o switch |

5G

# Silicon Offers Highest Integration

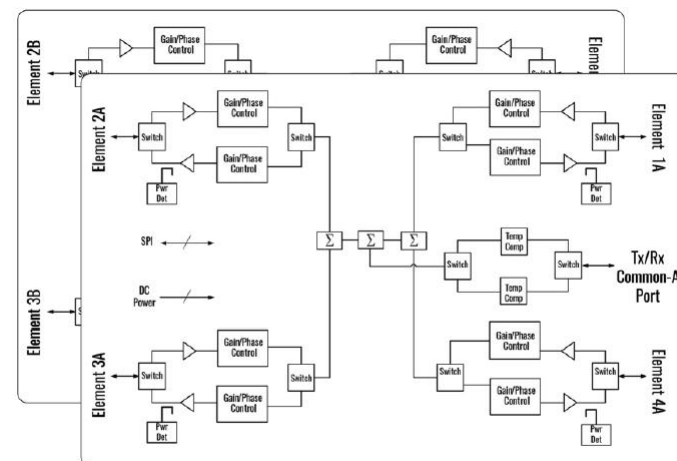


- Multiple RF channels per IC – Quad BFIC
- No external switches, LNA or PA
- Single positive supply operation
- High density circuit integration
- Compact QFN or WLCSP packages
- Fits half-lambda antenna element spacing
- Combines analog and digital circuits (SoC)

# 28 GHz TDD and 5G Quad Beamformer ICs

|                             | Gen 1  | Gen 2.5  | Gen 3  |
|-----------------------------|--|--|--|
| Specifications              | AWMF-0108                                    | AWMF-0158  | AWMF-0151  |
| Frequency                   | 26.5-29.5 GHz                                | 26.5-29.5 GHz  | 26.5-29.5 GHz  |
| Description                 | TDD Half Duplex                              | TDD Half Duplex                                      | TDD Half Duplex                                      |
| Polarization                | Single Pol                                   | Single Pol   | <b>Dual Pol</b>                                      |
| Phase and Amplitude control | 5 – bit phase (LSB=11.2°)<br>0-31 dB, 5 bits | <b>6 – bit phase</b> (LSB=5.6°)<br>0-15.5 dB, 5 bits | <b>6 – bit phase</b> (LSB=5.6°)<br>0-15.5 dB, 5 bits |
| DC Supply                   | 1.8V   | 1.8V/2.5V Dual Supply                                | 1.8V Supply  |
| Package                     | QFN  | WLCSP  | WLCSP  |
| Operating Temp              | -40 to +95C                                  | -40 to +95C  | -40 to +95C  |
| Features                    | Telemetry                                    | FBS, Telemetry, 3GPP compliance                      | FBS, Telemetry, 3GPP compliance                      |
| ECCN                        | 5A991.g                                      | 5A991.g  | 5A991.g  |

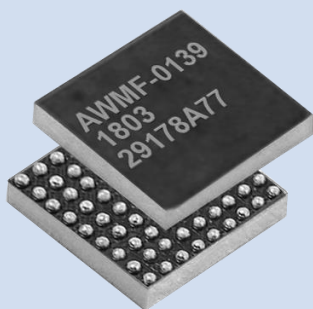
Release  
Q1 2019



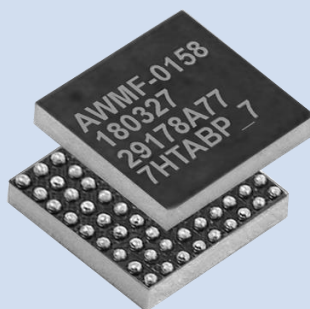


# Cover all 3 CPE frequencies

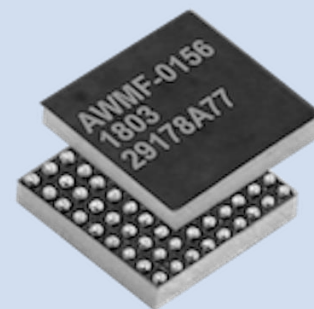
**24/26 GHz**



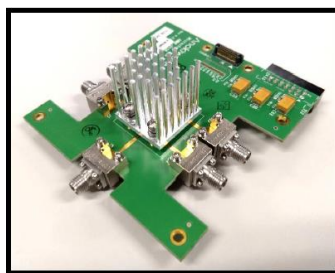
**28 GHz**



**37/39 GHz**



Eval board



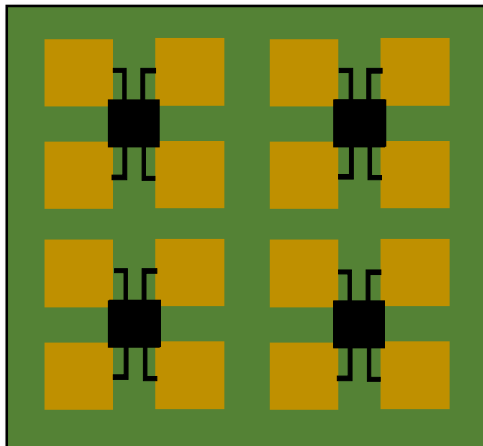
Same Pinout

Same SPI Interface

# General Architecture Options

# Single Pol IC Architecture Options

Simple  
4 Channel IC



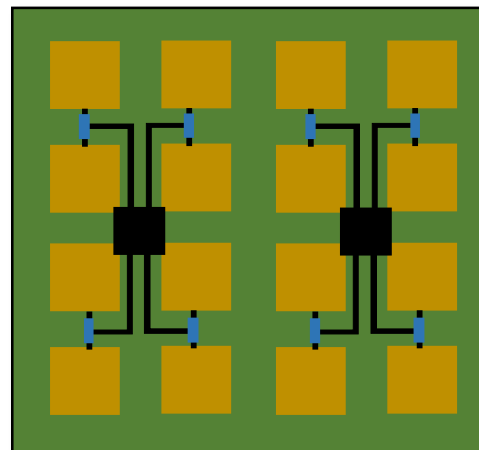
## Advantages:

- Simple layout (less layers, easy routing)
- Wide scan volume (AZ/EL)

## Disadvantages:

- High DC power
- High number of ICs

Split Feed  
4 Channel IC



## Advantages:

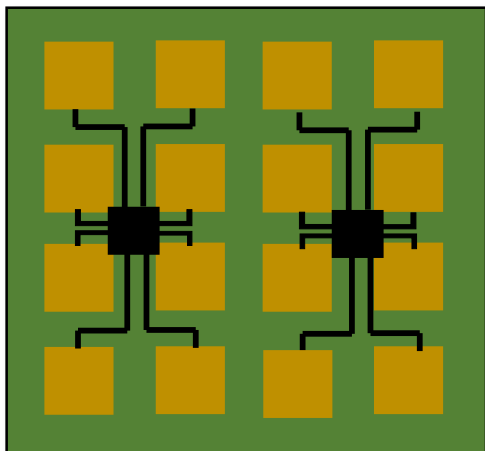
- Half of the number BFICs
- Lower DC power
- Lower Cost

## Disadvantages:

- Lower EIRP
- Higher loss

# Single Pol IC Architecture Options (2)

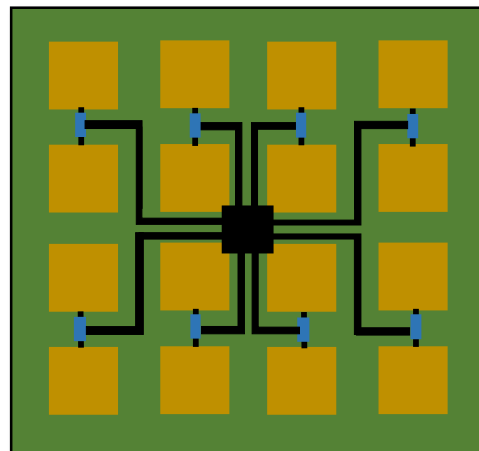
8 Channel IC



Advantages:

- Reduced number BFICs
- Lower DC power
- Lower Cost

Split Feed  
8 Channel IC



Advantages:

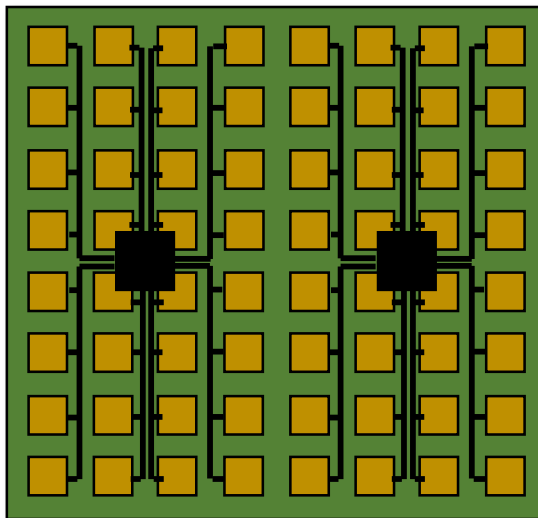
- Half of the number BFICs
- Lower DC power
- Lower Cost

Disadvantages:

- Lower EIRP
- Higher Loss

# Single Pol IC Architecture Options (3)

8 Channel IC, Column-Fed



## Advantages:

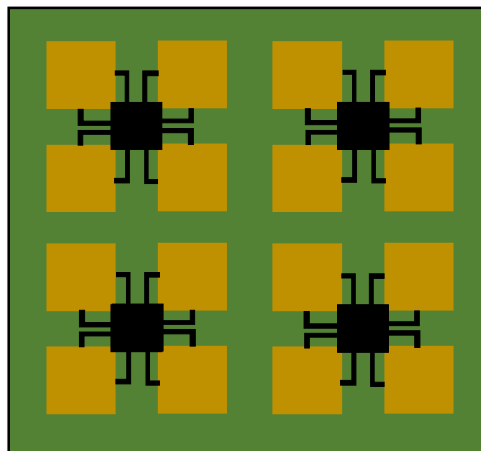
- High EIRP
- Reduced number BFICs
- Low number ICs
- Lower DC power
- Lower Cost

## Disadvantages:

- High loss
- Larger array

# Dual Pol IC Architecture Options

8 Channel, Dual Pol IC



## Advantages:

- Additional polarization (2 pol)
- Higher EIRP

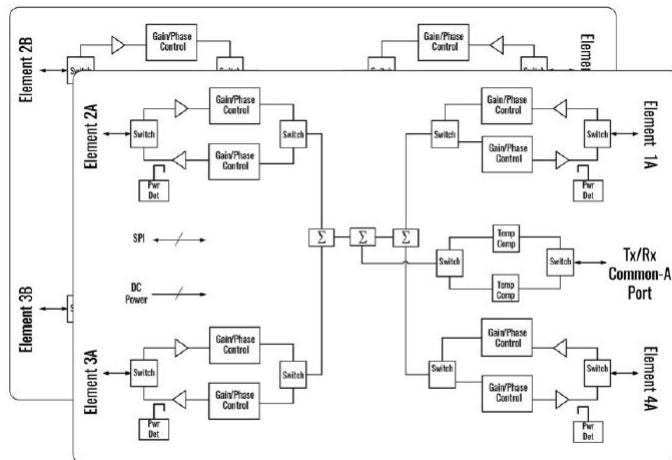
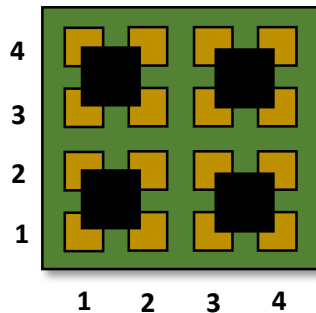
## Disadvantages:

- Higher DC power
- Higher number of ICs

# CPE examples

# Option 1: 16-Elements

## 8 Channel IC, 2 Pol per IC

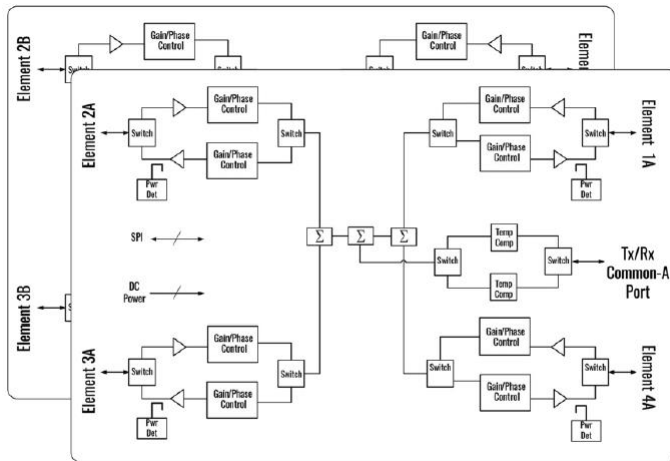
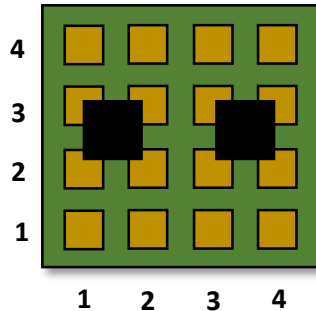


| Key Parameters           | Array Specifications  |
|--------------------------|---|
| Number of Elements       | 16 - elements ( 4 x 4 )   |
| EIRP per pol             | <b>37.2 dBm</b>   |
| Rx NF                    | 4.5 dB  |
| Power Consumption        | Higher DC Power   |
| Lattice (AZ/EL)          | 0.5 / 0.65 Lattice (d/λ)  |
| Scan Volume              | 60 / 20 Degrees   |
| Polarization             | <b>Two Pol</b>  |
| Phase/ Amplitude control | 6 – bit phase   |
| Description              | TDD Half Duplex   |
| DC Supply                | 1.8V Supply   |
| Operating Temp           | -40 to +95C   |
| Key Features             | Temperature Compensation<br>Power Detector<br>3D Beam Steering<br>Zero-Cal™ |



# Option 2: 16-Elements

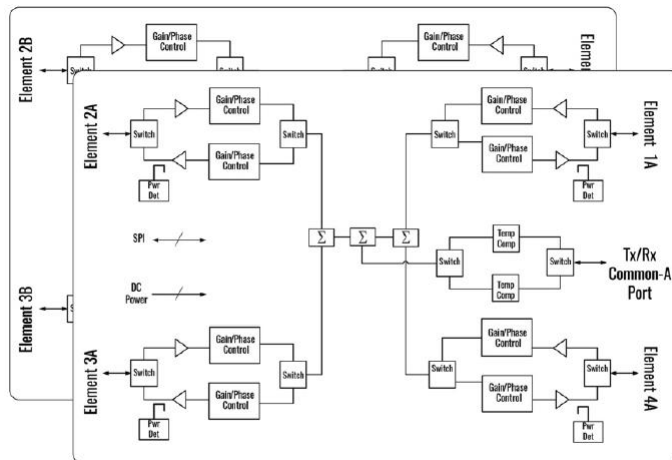
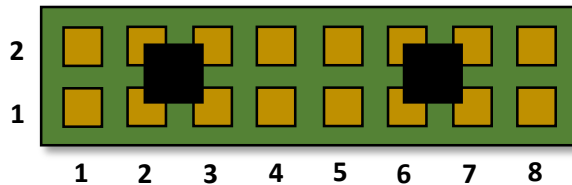
8 Channel IC



| Key Parameters           | Array Specifications  |
|--------------------------|---|
| Number of Elements       | 16 - elements ( 4 x 4 )   |
| EIRP per pol             | <b>36.7 dBm</b>   |
| Rx NF                    | 5.0 dB  |
| Power Consumption        | PoE Compatible  |
| Lattice (AZ/EL)          | 0.5 / 0.65 Lattice (d/λ)  |
| Scan Volume              | 60 / 20 Degrees   |
| Polarization             | One Pol   |
| Phase/ Amplitude control | 6 – bit phase   |
| Description              | TDD Half Duplex   |
| DC Supply                | 1.8V Supply   |
| Operating Temp           | -40 to +95C   |
| Key Features             | Temperature Compensation<br>Power Detector<br>3D Beam Steering<br>Zero-Cal™ |

# Option 3: 16-Elements

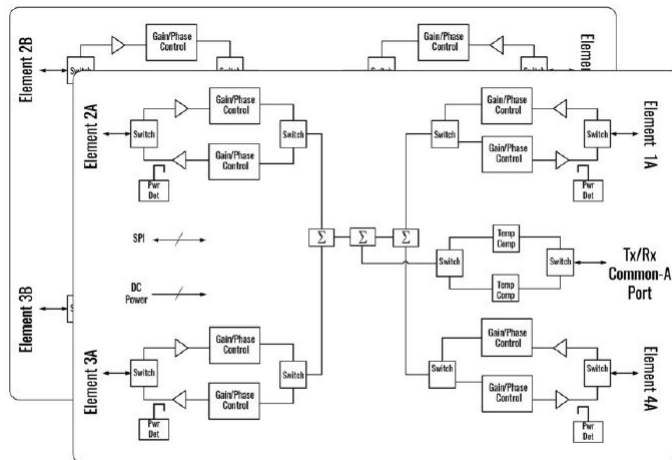
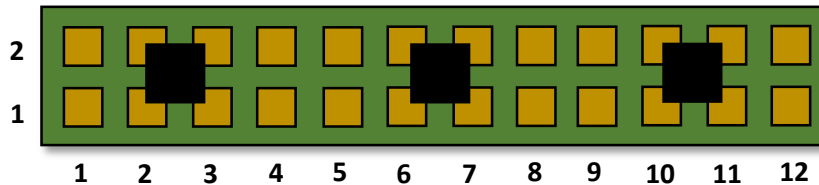
8 Channel IC



| Key Parameters           | Array Specifications  |
|--------------------------|---|
| Number of Elements       | 16 - elements ( 2 x 8 )   |
| EIRP per pol             | <b>37.9 dBmi</b>  |
| Rx NF                    | 5.0 dB  |
| Power Consumption        | PoE Compatible  |
| Lattice (AZ/EL)          | 0.5 / 0.85 Lattice (d/λ)  |
| Scan Volume              | 60 / -- Degrees ( <i>No Elevation scan</i> )                                |
| Polarization             | One Pol   |
| Phase/ Amplitude control | 6 – bit phase   |
| Description              | TDD Half Duplex   |
| DC Supply                | 1.8V Supply   |
| Operating Temp           | -40 to +95C   |
| Key Features             | Temperature Compensation<br>Power Detector<br>3D Beam Steering<br>Zero-Cal™ |

# Option 4: 24-Elements

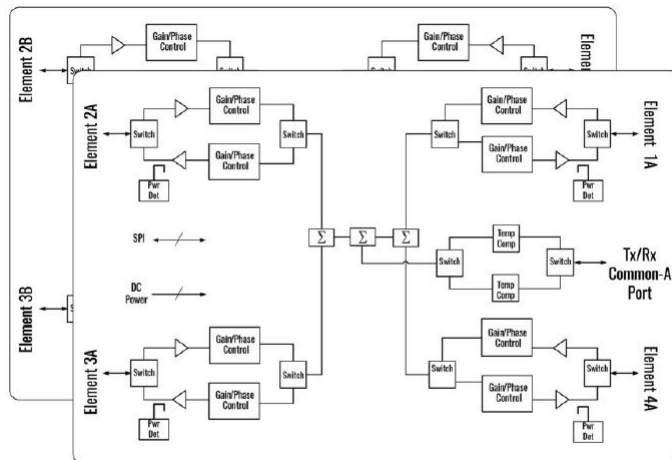
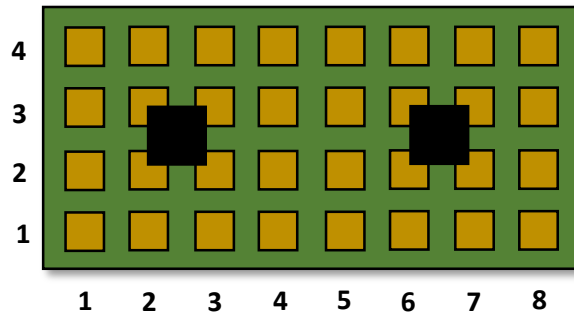
8 Channel IC



| Key Parameters           | Array Specifications  |
|--------------------------|---|
| Number of Elements       | 24 - elements ( 2 x 12 )  |
| EIRP per pol             | <b>41.4 dBmi</b>  |
| Rx NF                    | 5.0 dB  |
| Power Consumption        | Higher DC Power   |
| Lattice (AZ/EL)          | 0.5 / 0.85 Lattice (d/λ)  |
| Scan Volume              | 60 / -- Degrees ( <i>No Elevation scan</i> )                                |
| Polarization             | One Pol   |
| Phase/ Amplitude control | 6 – bit phase   |
| Description              | TDD Half Duplex   |
| DC Supply                | 1.8V Supply   |
| Operating Temp           | -40 to +95C   |
| Key Features             | Temperature Compensation<br>Power Detector<br>3D Beam Steering<br>Zero-Cal™ |

# Option 5: 32-Elements

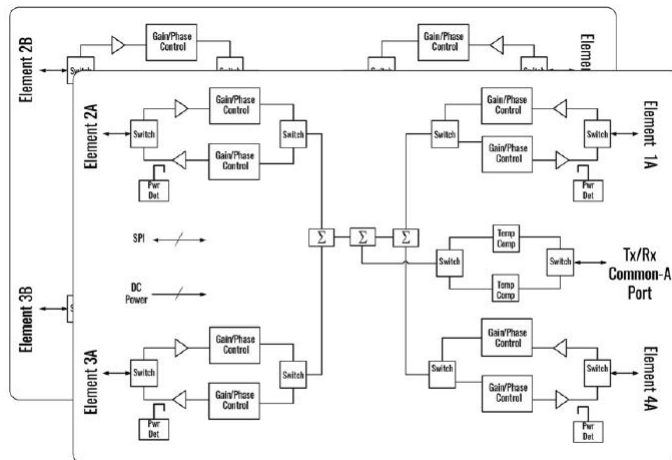
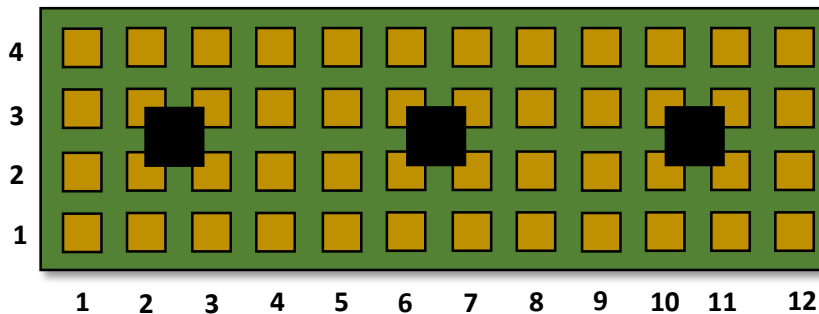
8 Channel IC, split-feed



| Key Parameters           | Array Specifications  |
|--------------------------|---|
| Number of Elements       | 32 - elements ( 4 x 8 )   |
| EIRP per pol             | <b>39.2 dBm</b>   |
| Rx NF                    | 5.5 dB  |
| Power Consumption        | PoE Compatible  |
| Lattice (AZ/EL)          | 0.5 / 0.65 Lattice (d/λ)  |
| Scan Volume              | 60 / 20 Degrees   |
| Polarization             | One Pol   |
| Phase/ Amplitude control | 6 – bit phase   |
| Description              | TDD Half Duplex   |
| DC Supply                | 1.8V Supply   |
| Operating Temp           | -40 to +95C   |
| Key Features             | Temperature Compensation<br>Power Detector<br>3D Beam Steering<br>Zero-Cal™ |

# Option 6: 48-Elements

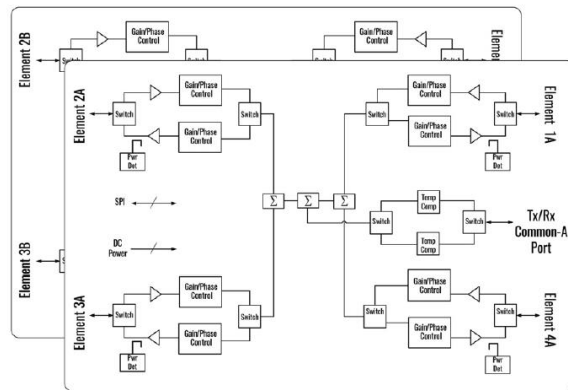
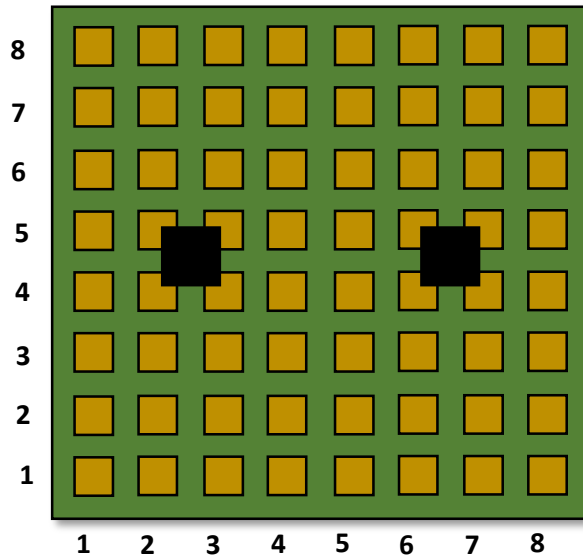
## 8 Channel IC, split-feed



| Key Parameters           | Array Specifications  |
|--------------------------|---|
| Number of Elements       | 48 - elements ( 4 x 12 )  |
| EIRP per pol             | <b>42.7 dBm</b>   |
| Rx NF                    | 5.5 dB  |
| Power Consumption        | Higher DC Power   |
| Lattice (AZ/EL)          | 0.5 / 0.65 Lattice (d/λ)  |
| Scan Volume              | 60 / 20 Degrees   |
| Polarization             | One Pol   |
| Phase/ Amplitude control | 6 – bit phase   |
| Description              | TDD Half Duplex   |
| DC Supply                | 1.8V Supply   |
| Operating Temp           | -40 to +95C   |
| Key Features             | Temperature Compensation<br>Power Detector<br>3D Beam Steering<br>Zero-Cal™ |

# Option 7: 64-Elements

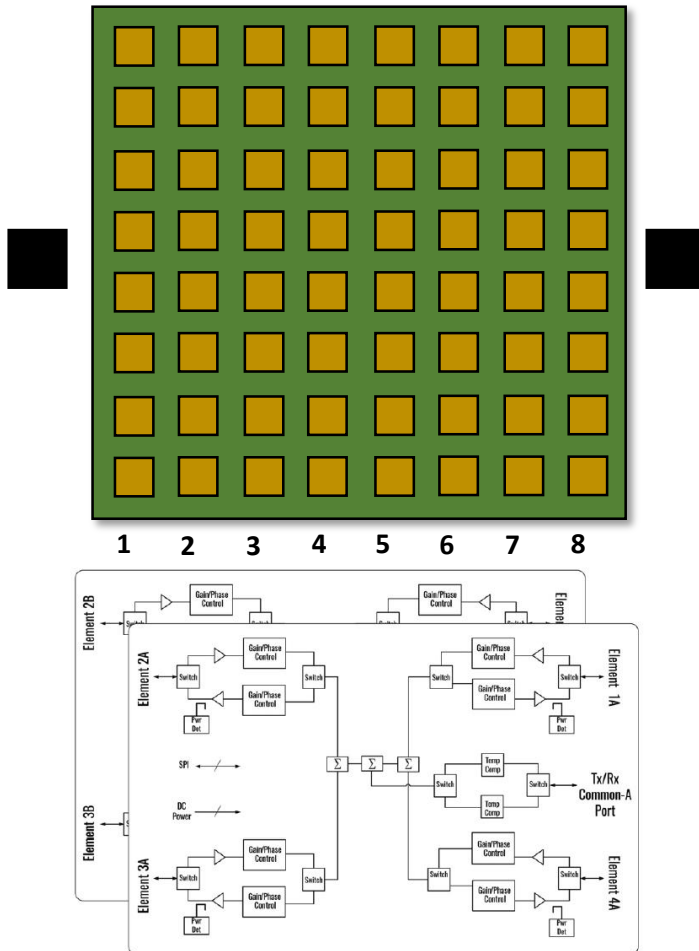
8 Channel IC, column-fed



| Key Parameters           | Array Specifications  |
|--------------------------|---|
| Number of Elements       | 64 - elements ( 8 x 8 )   |
| EIRP per pol             | <b>41.2 dBm</b>   |
| Rx NF                    | 6.5 dB  |
| Power Consumption        | PoE Compatible  |
| Lattice (AZ/EL)          | 0.5 / 0.65 Lattice (d/λ)  |
| Scan Volume              | 60 / 20 Degrees   |
| Polarization             | One Pol   |
| Phase/ Amplitude control | 6 – bit phase   |
| Description              | TDD Half Duplex   |
| DC Supply                | 1.8V Supply   |
| Operating Temp           | -40 to +95C   |
| Key Features             | Temperature Compensation<br>Power Detector<br>3D Beam Steering<br>Zero-Cal™ |

# Option 8: 64-Element

8 Channel IC, row-fed



| Key Parameters           | Array Specifications  |
|--------------------------|---|
| Number of Elements       | 64 - elements ( 8 x 8 )   |
| EIRP per pol             | <b>36.7 dBm</b>   |
| Rx NF                    | 8.0 dB  |
| Power Consumption        | Higher DC Power   |
| Lattice (AZ/EL)          | 0.5 / 0.65 Lattice (d/λ)  |
| Scan Volume              | 60 / 20 Degrees   |
| Polarization             | <b>Two Pol</b>  |
| Phase/ Amplitude control | 6 – bit phase   |
| Description              | TDD Half Duplex   |
| DC Supply                | 1.8V Supply   |
| Operating Temp           | -40 to +95C   |
| Key Features             | Temperature Compensation<br>Power Detector<br>3D Beam Steering<br>Zero-Cal™ |

# CPE Analyzed and Antenna Options

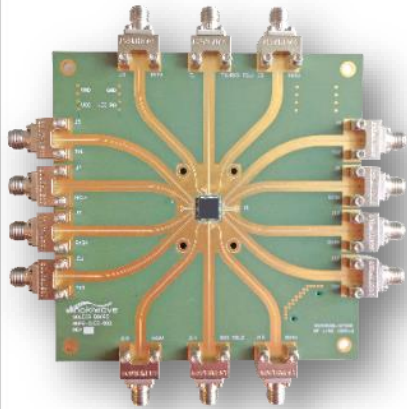
| Layout Type | Number of Elements | # BFIC | Number of Polarization | Scanning (Deg) | EIRP (dBm) | RX NF (dB) | Power Consumption |                                  |
|-------------|--------------------|--------|------------------------|----------------|------------|------------|-------------------|----------------------------------|
| 4 x 4       | 16                 | 4      | 2                      | 60 / 20        | 37.2       | 4.5        | High              |                                  |
| 4 x 4       | 16                 | 2      | 1                      | 60 / 20        | 36.7       | 5.0        | Low               |                                  |
| 2 x 8       | 16                 | 2      | 1                      | 60 / --        | 37.9       | 5.0        | Low               |                                  |
| 2 x 12      | 24                 | 3      | 1                      | 60 / --        | 41.4       | 5.0        | Mid               |                                  |
| 4 x 8       | 32                 | 2      | 1                      | 60 / 20        | 39.2       | 5.5        | Low               | Suggested<br>High<br>Performance |
| 4 x 8       | 48                 | 3      | 1                      | 60 / 20        | 42.7       | 5.5        | Mid               |                                  |
| 8 x 8       | 64                 | 2      | 1                      | 60 / 20        | 41.2       | 6.2        | Low               |                                  |
| 8 x 8       | 64                 | 2      | 2                      | 60 / 20        | 36.7       | 8.0        | Mid               |                                  |



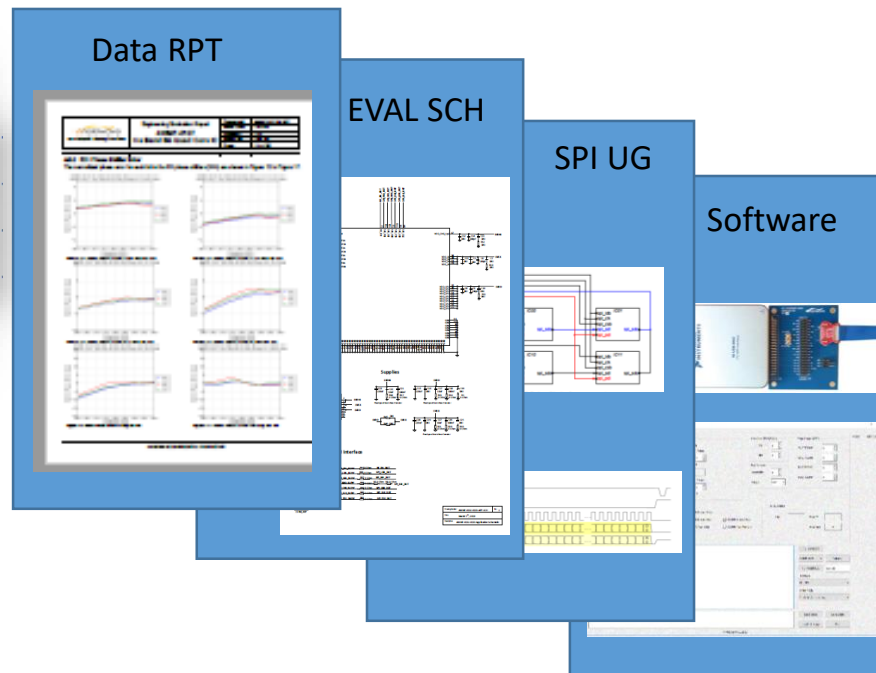
# **When you buy Anokiwave**

# Eval Board / Report

- Includes all HW required for device interface and optionally includes 25 extra ICs
- Test board designed to provide the necessary channel to channel isolation
- Includes custom GUI to easily control test board
- Comprehensive performance data included

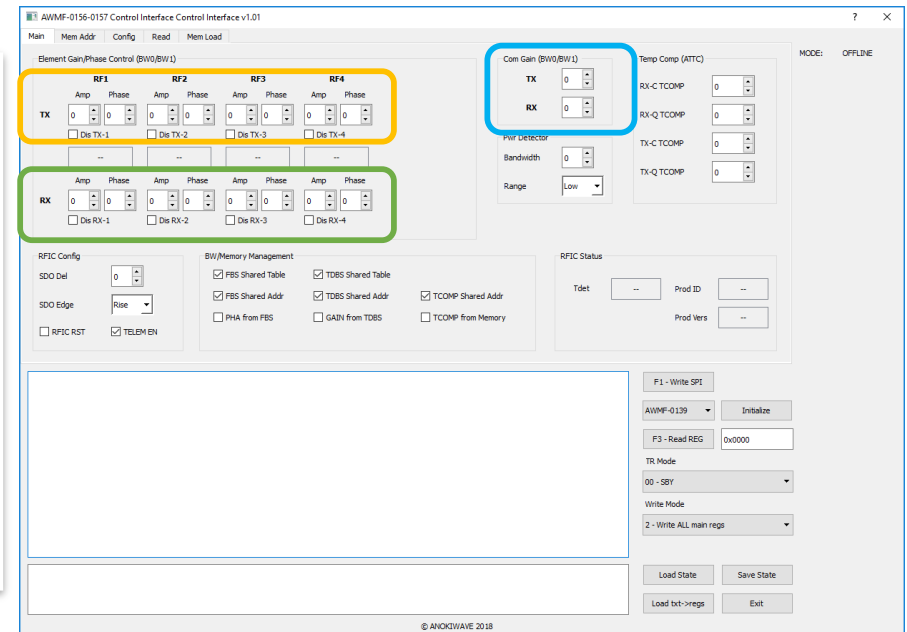
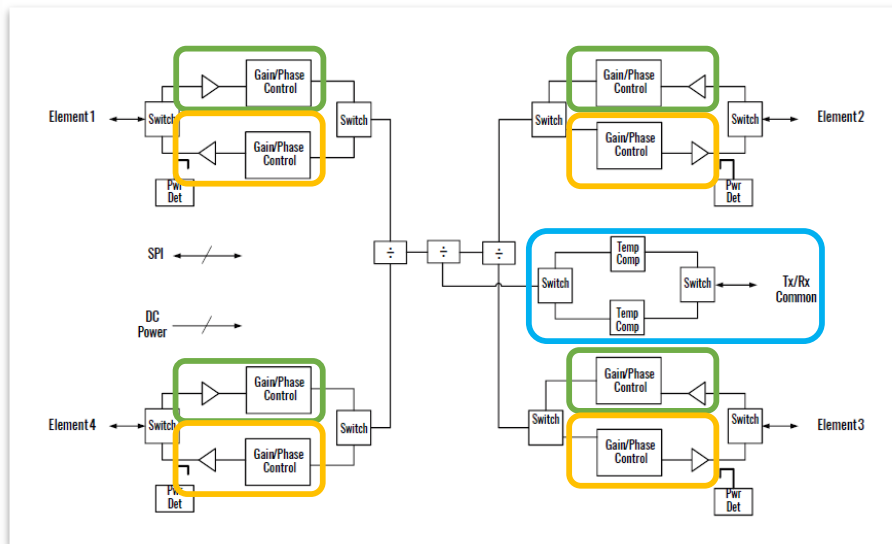


Test Board with IC



Kit includes all interface hardware

# GUI



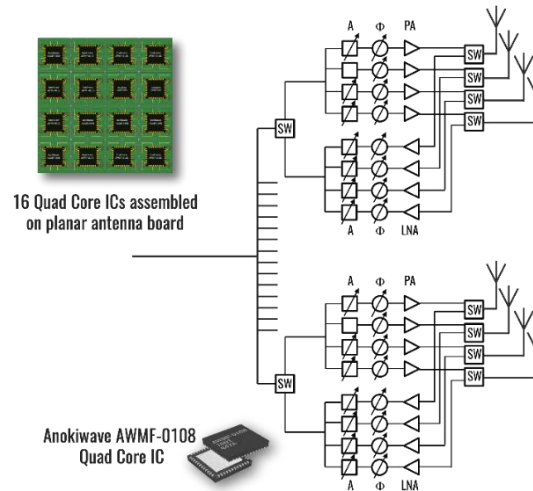
**We did it already**  
Anokiwave your preferred IC provider

# Because Our ICs Work in Arrays!

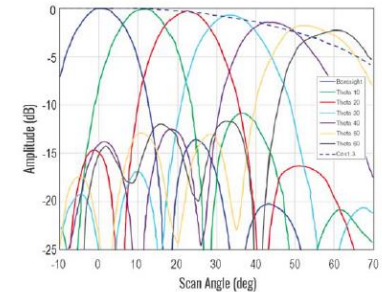
AWMF-0129: 28 GHz, 64-Element  
Active Antenna Innovator's Kit

## KEY FEATURES:

- **27.5 – 30 GHz** frequency range
- Half Duplex Tx/Rx TDD operation
- 2D electronic beam scan
- $\pm 60^\circ$  AZ and EL electronic scan
- Linear polarization
- Single beam with adaptive beam width and SLL
- **+50 dBm (100W) Tx EIRP with 12W Pdc**
- **-7 dB/K G/T** Rx sensitivity
- 13us beam update rate
- Temperature sense telemetry
- Scalable for hybrid beamforming MU-MIMO
- ECCN Classification: 5A991.f



Anokiwave AWMF-0129  
64 Element Active Antenna

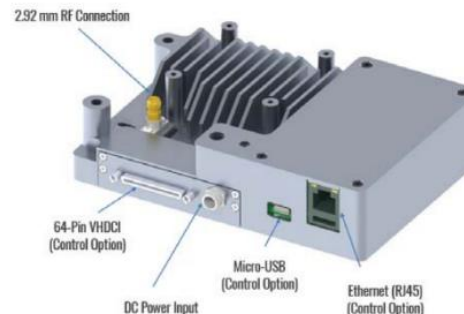


Short Video:

<https://youtu.be/VUCw8UHLT30>

Long Video:

<https://goo.gl/photos/buiSiriPiEqzyB6FA>



## Includes:

- AWMF-0129 Active antenna
- USB with GUI files and drivers
- Power cord, Ethernet cord, Micro-USB
- Tripod with mount and adapter
- Phillips screw driver and screws

# Why Anokiwave?

- Only company with mmW Active Antenna IC solution for **24/26GHz, 28GHz, 39GHz for 5G applications**
- Deep system level expertise and experience
- Close customer support and collaboration:
  - System level analysis
  - Application Support
  - PCB guidelines
  - Antenna design guidelines
- Already a preferred choice of tier 1, 2 OEMs for AESA products
- Real deployed radios in the market with Anokiwave ICs